Study of 1200dpi High Resolution Thermal Print Head

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Abstract

This paper is intended as an evaluation of a high-resolution thermal print head exceeding 600dpi. In the preceding paper we reported on the optimum structure and shape for 600dpi-head based on a series of experiments on thermal diffusivity of various materials possibly used as components. In the process of development we reached a two-ply structure consisted of a Si-single-crystal substrate superior in heat conductivity and a low thermal diffusion layer sputtered over the substrate. Carrying out FEM analysis of a 1200dpi-head of the above structure, we came to the conclusion that high resolution up of to 1200dpi was technically achievable. We also confirmed the possibility through print test.

Introduction

Printers, from office use to individual home use, have been increasing in print resolution daily and those featuring 1000dpi or more are almost the mainstream in the market today. We have so far achieved the first goal of 600dpi in thermal transfer printing by improving various factors such as head structure and ink material.[1-4] Also, in the pursuit of better image quality on various output devices, it is a matter of urgency for printers providing only binary mode to realize multi-level tone printing. For this reason we have strived to make further improvement to the thermal head with the aim of achieving multi-level tone printing employing resin ink, which led us to develop the new technology called Variable Dot Photo (VPhoto).[5] Recent strong demand for higher resolution, however, forces thermal printers, often applied as a proofer thanks to its similarity in printing process and ink property to commercial print, to attain higher resolution, too. In addition widespread use of digital still camera reproducing high pixel-density images makes it more important for output devices to reach photographic print quality by attempting higher resolution. Therefore, adopting thermal analysis, we examined 1200dpi-head without changing the present structure of Micro DOS head in respect of whether it can realize satisfactory resolution.

Head Structure

The Thermal print head used in a series of analysis and experiments has the structure as shown in Figure 1. It is a 1200dpi-head consisting of 240 heating elements lined-up at 21micron intervals and designed for a serial printer that prints a band of 0.2-inch width at every carriage movement. Driver IC chip is mounted in TAB (Tape Automated Bonding). Dimensions of the head are 18 mm × 8.0mm × 0.8mm. TAB and the head are soldered at terminal pitch of 70micron. Si single crystal is employed as material of the substrate and the heat insulation layer is a silicon-based-alloy reactive sputtered film with a low-density columnar structure approximately 20micron thick. This is the same structure as Micro DOS head already in practical use. The heating elements are formed on a protruding part of the substrate with the aim of fixing resin ink firmly onto even plain paper, which contributes to concentration of the load applied to the head on the heating elements. When it comes to ink releasing from base film and transferring it onto print medium, ink transference characteristic is highly influenced by edge distance, the length from the center of the heating elements to the head edge. The Edge distance of Micro DOS head is approximately 130micron. As shown in Figure 1, a shallow trench is formed between the heating elements and the head edge, and a common electrode is buried in the trench. Also, there is a flat area of approximately 20micron on the very end of the head edge where takes an important role in fixing resin ink.

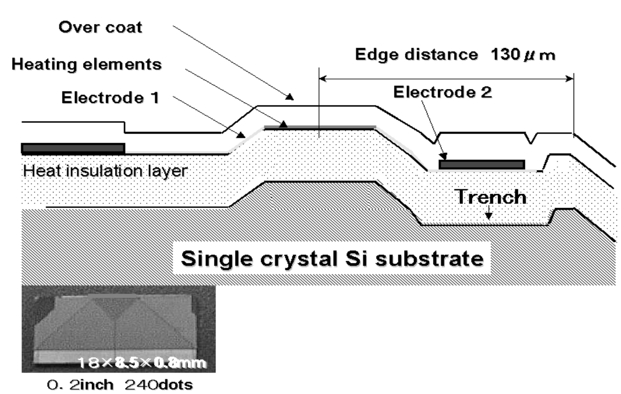

Figure 1. Structure of Micro DOS Head

Evaluation of Technical Subjects: Analysis by FEM (Finite Element Method)

We applied FEM to the evaluation of technical subjects on 1200dpi-head. Figure 2 is the FEM analysis model and Table 1 shows material properties of the head, ink ribbon and print paper. We used ANSYS5.6, an FEM analytic software program, as the means for two-dimensional analysis. Assuming a model simulating relative motion of the head and media (ink and paper), the analysis employed Mass Transport function of the software. Heat conduction equation of the model is given as in Equation 1. In the analysis of the head, we first analyzed condition of three continuous dots which two of them energized and one in the middle not energized and then evaluated the relationship between shift in ink temperature and amount of relative motion of the head and ink. Figure 3 shows the relationship schematically. We evaluated ink-transferring condition from the relation of threshold of printing to peak and valley ink-temperature, and then found out required minimum head temperature after the head peak temperature in Figure 3. We also examined relationship between resolution and optimum edge distance by analyzing in which position ink reached to peak temperature in each relative-motion model in different resolution.

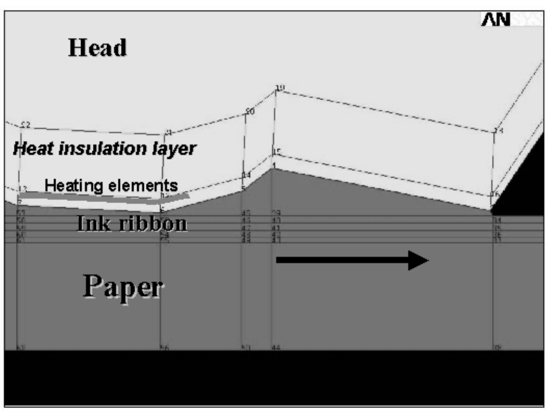

Figure 2.FEM analysis model

Thermal Response Characteristics

Required driving frequency of the head to perform 10 IPS (inch per second) at 1200dpi is 12kHz, however, if heating elements are switched-on and -off at this frequency, the substrate holds too much heat, which results in blurred and swollen printed dots overlapped each other. Furthermore it is also difficult to control head temperature at a certain level. Thus, for the aim of high-speed and high-density print in thermal transference, quick thermal response of the head is essential. The analysis found that Micro DOS head has a suitable structure for this purpose. Figure 4 indicates how head structure and heat insulation layer influence thermal response. The figure reveals that it is difficult to drive conventional head at 1200dpi and the speed of 10 IPS due to the valley temperature comparatively higher than others, and also that Micro DOS head can be driven at the ideal condition by adjusting the heat insulating layer to 10micron thickness or less.

Table1, Materials Properties

Materials	Thermal conductivity λ (w/mK)	Specific heat c(J/kgK)	Density ρ (kg/m^3)
Si substrate	150	805	2330
Heat insulation layer	1.2	1800	1000
Heater	45	700	6500
Over coat	3	1000	3200
PET	0.14	1340	1400
Paraffin	0.32	2520	940
Ink	0.349	2440	980
Paper	0.06	1170	1050

$$\rho c\left(\frac{\partial T}{\partial t}+vx\frac{\partial T}{\partial x}+vz\frac{\partial T}{\partial y}+vz\frac{\partial T}{\partial z}\right)+\lambda\frac{\partial^2 T}{\partial x^2}+\lambda\frac{\partial^2 T}{\partial y^2}+\lambda\frac{\partial^2 T}{\partial z^2}=Q \qquad (1)$$

ρ: *Density*
c: *Specific Heat*
T: *Temperature*
t: *Time*
vx, vy, vz: *Velocity of a moving fluid*
λ: *Thermal conductivity*
Q: *Generation of heat*

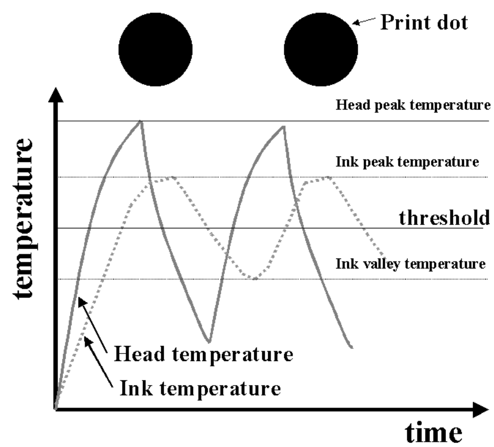

Figure 3.Relationship between dot diameter and head temperature or ink temperature

Head Temperature: Heat Resistance Characteristic

Presuming driving speed of 10 IPS, we analyzed the relationship between print resolution and head surface temperature required for heating up the ink to 80 degrees centigrade. The result appears in Figure 5. As the figure shows, higher resolution requires higher head surface temperature. As for 1200dpi-head, since high temperature of 800 degrees centigrade is necessary, conventional glazed-aluminum head can't achieve 1200dpi due to the limit of heat resistance in its glazed layer. Whereas, Micro DOS head has the great possibility thanks to the components: Si single crystal for the substrate and silicon-alloy reactive sputtered film for the heat insulation layer. We can recognize from these facts that the structure of Micro DOS head is essential to achieve 1200dpi at 10 IPS.

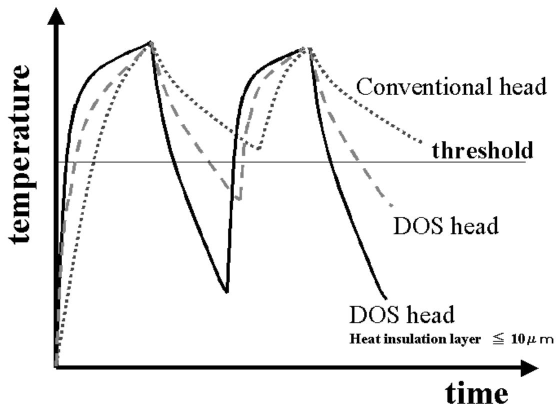

Figure 4. Relationship between head structure and thermal response

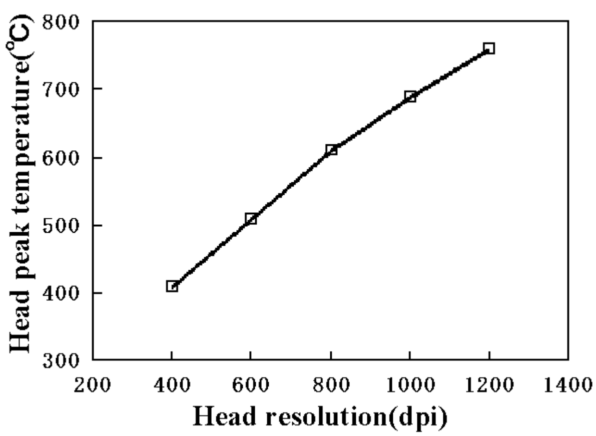

Figure 5.Relationship between print resolution and head surface temperature required for heating up the ink at 80 degrees centigrade

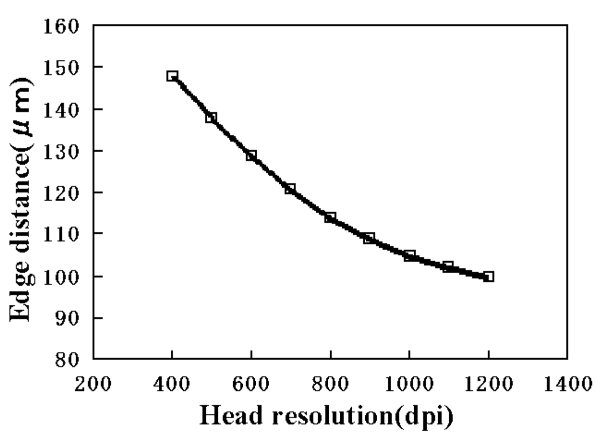

Figure 6.Optimum edge distance in varied prints resolution

Head Shape: Edge Distance

In the process of ink releasing and transferring, ink transference characteristic is highly related to edge distance.

Optimum edge distance in varied print resolution appears in Figure 6. As the figure shows, optimum edge distance for 1200dpi is given as approximately 100micron, while 130micron for 600dpi. If we attempt to shorten edge distance according to the above fact, electrode width is inevitably narrowed, and this increases electrical resistance of the electrode placed on the head edge, which results in voltage drop-down. This structural problem calls for further study as the next issue.

Testing of Prototype

Considering technical subjects of 1200dpi-head cleared by FEM analysis, we made a prototype and evaluated its properties. The prototype has the same structure as the present 600dpi head. MD5500 was used in the print test as a printer mechanism, VPhoto film as print paper and TYPE-MD as ink, all original products of Alps Electric Co., Ltd.

Relationship of Head Peak-Temperature to Input Power in Different Resolution

Figure 7 shows the relationship between input power to head peak-temperature after energizing for 100 microseconds' duration. It follows that a head performing higher resolution tends to generate heat easily by lower power. This result is summarized by input energy and head peak-temperature per unit area as seen in Figure 8, each point drawn linearly, and this makes it clear that heat generation phenomenon on the head is in proportion to input energy per unit area.

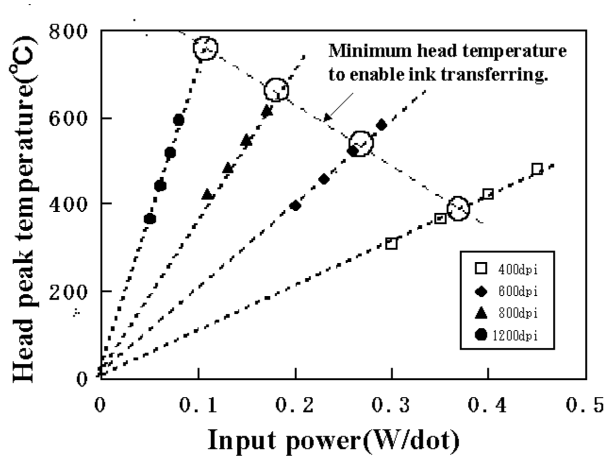

Figure 7. Relationship between input power and head peak temperature.

Relationship of Required Minimum Head-Temperature to Resolution

Looking back to Figure 7 again, it also shows relationship between minimum input power to enable ink transferring and head temperature on that power in a series of print test varied in resolution. The figure indicates that higher resolution requires higher head temperature. This agrees with the result of FEM analysis seen in Figure 5. Thus we concluded that head peak-temperature of approximately 800 degrees centigrade is needed to materialize 1200dpi-head.

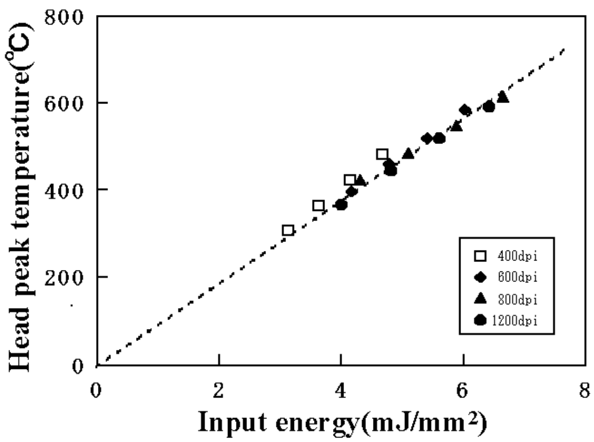

Figure 8.Relationship between input energy and head peak temperature

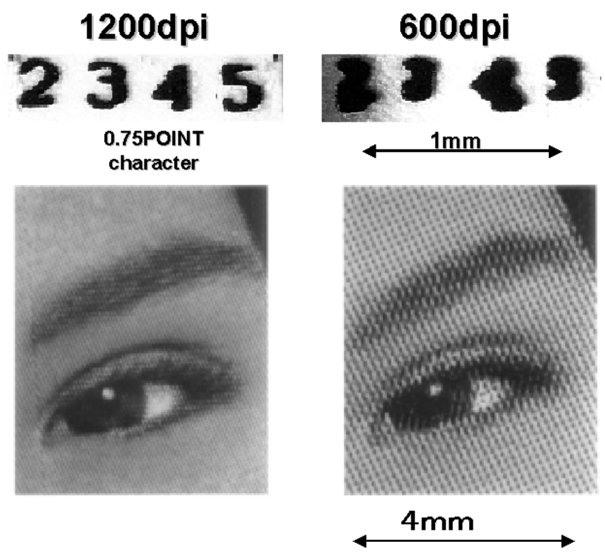

Figure 9.Comparison of print quality

Comparison of Print Quality

We furthermore compared quality of printouts processed by the prototype to printouts by 600dpi head. Some of the print samples of characters and images are shown in Figure 9. Print quality of characters is greatly improved and even minute characters even smaller than 1-point are reproduced satisfactorily. In addition high-density images of 370lpi (line per inch) can be also attainable, while 600dpi-head only reaches up to 190lpi, and the 1200dpi-head provides higher definition than 600dpi-head.

Conclusion

We confirmed through FEM analysis that the high resolution printing of 1200dpi can be realized by adopting the structure of Micro DOS head. We also found that varying thickness of heat-insulation layer on Micro DOS head enables high-speed printing. This means that enhancement in heat resistance of the head is needed since higher head-surface temperature than that of conventional head is required at the print speed. In resin ink transferring, edge distance is the key to high print quality, and it should be designed shorter than that on 600dpi-head. And it suggests that appropriate positioning of common electrode buried in the head-edge is the next technical subject to be solved. We made a prototype of 1200dpi print head for experiment and evaluated the print quality through print test, which let us assure possibility of the expected high-resolution printing.

Afterword

We have found that thermal response of Micro DOS head consisted of Si substrate and Si-alloy reactive sputtered heat-insulation layer contributes to materialization of 1200dpi-head. And at the same time we strongly believe that printers equipped with Micro DOS head will surely provide almost the same image quality as offset printing and the same photographic quality approaching that of silver halide imaging.

References

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Biography

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in1991. He has worked at Alps Electric Co., Ltd. System Devices Division since 1991 and is currently a researcher in the R&D department. His interests are in research and development of thermal transfer technology and thermal print head. He received a technical award from The Society of the Electrophotography of Japan in 1996. E-mail address: teraohit@alps.co.jp